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BUREAU OF PLANT INDUSTRY—BULLETIN NO. 87.
B. T. GALLOWAY, *Chief of Bureau.*

DISEASE RESISTANCE OF POTATOES.

BY

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Station and Collaborator of the Bureau
of Plant Industry.

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL
INVESTIGATIONS.

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BUREAU OF PLANT INDUSTRY.

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Pathologist and Physiologist, and Chief of Bureau.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., October 7, 1905.

Sir: I have the honor to transmit herewith the manuscript of a technical paper entitled "Disease Resistance of Potatoes," which embodies a report upon investigations conducted in cooperation with the Vermont Agricultural Experiment Station.

This paper is a valuable contribution to our knowledge of disease resistance in European and American varieties of potatoes, and I respectfully recommend that it be issued as Bulletin No. 87 of the series of this Bureau.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The potato is one of the most important food crops of the United States. It is, moreover, one which is subject to a number of serious plant diseases. Some of these, notably the late-blight, can be controlled by spraying. Yet this remedy is not applied by all farmers, and the annual loss amounts to many millions of dollars. Other diseases, like dry-rot and the bacterial blight, are not controlled by spraying and require a different line of treatment. The subject of disease resistance in plants has received increased attention of late, and it is likely that the introduction of disease-resistant varieties of potatoes, by supplementing spraying and special cultural practices, will be of great practical value in lessening the waste caused by disease. Although but little has been done in the United States toward securing varieties resistant to disease, the attention of potato specialists in other countries has already been directed toward this aim.

As a preliminary step in our work, Dr. L. R. Jones, botanist of the Vermont Agricultural Experiment Station, was commissioned to inquire into the occurrence of potato diseases abroad and the methods employed for their control, particularly with reference to the production of disease-resistant varieties. Doctor Jones spent six months—from April to September, 1904—in this work.

In the course of Doctor Jones's European itinerary, information of more or less value was secured at the following places, successively, and this was supplemented by a considerable correspondence covering a somewhat wider area: Marseille, Naples, Florence, Munich, Halle, Berlin and vicinity, Dresden and vicinity, Bonn and vicinity, Wageningen (Holland), Amsterdam and vicinity, Groningen, Delft, Gembloux (Belgium), Paris and vicinity, London and vicinity, Reading, Cambridge, and Edinburgh and vicinity. The thanks of the Department are accorded to the various officials and other botanists in the countries visited, whose uniform courtesies made possible the success of the mission.

As shown in this report, a considerable number of varieties are reputed to be disease resistant. The best of these were selected by Doctor Jones, and limited quantities of seed tubers were imported by the Office of Seed and Plant Introduction and Distribution of the

Bureau of Plant Industry. These are now being tested in trials conducted in cooperation by the Bureau of Plant Industry and the State experiment stations in Vermont, Florida, Colorado, and Oregon, and by the Bureau at the Arlington Experimental Farm, near Washington. In order fully to acclimatize the foreign varieties, these trials will be continued for three years before a final report is made on their adaptation to American conditions. This test, together with the review of our present knowledge contained in this bulletin, will establish a proper foundation for future efforts in breeding better and more disease-resistant varieties. The field for such work is very large. Up to the present time most of the breeding has been for resistance to the late-blight (*Phytophthora infestans*), and this will continue to be the principal problem in the northern tier of States; but there is also much promise of success in securing new varieties to resist scab, dry-rot, bacterial blight, and other troubles, which in the Southern and Western States are more injurious than late-blight. It is hoped that potato specialists will give increasingly careful attention to this feature in their breeding and testing of varieties, for it is only by such a general interest and effort that the desired information can quickly be secured.

ALBERT F. WOODS,
Pathologist and Physiologist.

OFFICE OF VEGETABLE PATHOLOGICAL AND
PHYSIOLOGICAL INVESTIGATIONS,
Washington, D. C., October 5, 1905.

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DISEASE RESISTANCE OF POTATOES.

INTRODUCTION.

Potatoes are liable to several diseases, some of greater economic importance in one part of the country, some in another.[a] The causes of most of these have been determined, and remedies of more or less practical value, chiefly spraying and seed disinfection, have been found. The success of the agents of the Department of Agriculture in securing disease-resistant varieties of various other plants has given an added interest to the question as to what may be expected in the way of securing disease-resistant varieties of potatoes. Inasmuch as this matter has engaged the attention of the potato specialists of Europe longer and more widely than has been the case in America, the attempt has been made to glean from their experience whatever may prove of assistance in furthering the work in this country.

In presenting the results it has seemed best for the sake of clearness to discuss briefly (1) certain general matters relating to potato culture in Europe; (2) the potato diseases which occur there, with comments on the resistance shown by particular varieties to each disease, and then (3) to summarize the information obtainable in America as to disease resistance of potatoes.

POTATO CULTURE IN EUROPE.

Potato culture was introduced from America into Europe more than three centuries ago. It was slower in its popularization there than in this country, but to-day the potato crop is relatively more important, both for food and for factory uses, in Europe than in America. This is partly attributable to the greater success of maize as a starch-producing plant in America and partly to the difference in economic conditions—land and labor values and food habits—between the two continents. In the British Islands the annual acreage in the last decade[a] was more than one and a quarter million; in France three times and in Germany six times this amount. The crop in Great Britain is chiefly used for human food; in France about 40 per cent is used in starch and alcohol manufacture, and in Germany like conditions exist, with the use of the potato for alcohol distillation promising to increase largely.

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[a] Anyone not familiar with potato diseases should consult Farmers Bulletin No. 91, Potato Diseases and Their Treatment, by B. T. Galloway, which will be sent free of charge upon application to a Senator, Representative, or Delegate in Congress, or to the Secretary of Agriculture, Washington, D. C.

It is the German national policy so to improve processes of culture and manufacture that potato alcohol may rival, if not displace, petroleum for lighting and fuel purposes. Various organizations are aiding in this movement, including the Deutschen-Kartoffel-Kultur-Station and the Institut für Gährungsgewerbe und Stärkefabrikation. These institutions, maintained partly by private endowment and membership and partly by government aid, have been in operation about fifteen years. Under the directorship of Profs. C. von Eckenbrecher and W. Delbrück, respectively, they give attention to all matters pertaining to potato culture, starch manufacture, and distillation, including the breeding, selecting, and trial of new varieties. They work in close cooperation with the various German experiment stations and private potato specialists. No similar institutions were met with elsewhere in Europe, although the potato growers of England have organized during the last year an association of much promise, the National Potato Society.

In any comparison of European with American varieties the difference in popular taste must be kept in mind. The English market is like the American in giving preference to varieties with white flesh, rich in starch, and in making little use of potatoes except for human food. On the continent of Europe, however, only the varieties with yellow flesh are rated as of first quality for table use. These are relatively poor in starch and richer in protein than the white-fleshed varieties, and when cooked they are not sufficiently dry and mealy to suit the American taste. On the Continent the white-fleshed, starch-rich potatoes are demanded by the starch factories and distilleries, and as a result continental potato breeders have aimed to develop white-fleshed varieties of high starch content and large productiveness, regardless of table qualities, and anyone importing their varieties for use in America must consider these facts. It is from England, therefore, that we may expect the more promising varieties.

It is worthy of note in this connection that the difference in character of the potato in popular favor in different countries is closely related to differences in methods of cooking. The varieties with yellow flesh are inclined to sogginess when baked or boiled, but are admirably suited for frying. The starch-rich white potato, which is of highest quality when baked, may go to pieces if boiled and will not hold together sufficiently for frying. In the latter case steam cooking gives better results than boiling in water.[a]

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[a] Sutton, A. W., Potatoes, Jour. Roy. Hort. Soc., XIX (1896), pp. 387–430.

The methods of culture of potatoes vary somewhat in different European countries, as they do in America. In general, closer planting is practiced than in this country, which is partly explained by the greater number of unskilled laborers in Europe. A matter of more pertinence to the present discussion is that much more attention is given, especially in England, to the source and handling of seed potatoes than is generally the case in America. The best informed English growers considered that this has much to do with the question of disease resistance, as will be explained later. Indeed, it has come to be accepted by them that, for the best results, seed potatoes should be imported from some more northern region, at least as often as every third or fourth year, and this is done by many large growers every year. English growers use Scotch seed very largely. On the grounds of Sutton & Sons, Reading, England, a comparative trial was conducted during the summer of 1904 with a number of varieties, using seed from Scotland, middle England (Lincolnshire), and southern England, respectively. When these plats were visited in August, the vigor of the plants was in all cases greatest from the Scotch-grown seed and least from that grown in the south of England. In certain varieties the development of the tops was as two to one. At the Cambridge University farms, located in the famous potato region of Lincolnshire fens, it was said that Scotch-grown seed did better than home-grown there and in the Lincolnshire district generally.

A large potato-growing company of the Canary Islands uses German in preference to English seed, because the growth from the latter is too rank and the tubers are too large. Potato growers on the island of Jersey in recent years have sent to England and Scotland for their seed. Italy and the Mediterranean islands look to France and Germany largely.

While some American potato growers recognize the importance of the source of seed and attend to this point consistently, there is generally indifference, disagreement, or lack of information on this subject, as Fraser[b] has recently shown. It is a matter deserving of further careful inquiry and experiment.

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[a] The writer is indebted to Professor Petermann for calling his attention to these matters. For a further discussion of this subject reference may be made to Petermann, A., Etudes sur la pomme de terre, Bul. de l'Inst. Chim. et Bact., No. 70, Gembloux (Belgium), 1901; and Coudon and Bussard, Annales de la science agronomique, I, Paris, 1897. To the latter, credit may be given for showing that the behavior of the potato in cooking is primarily dependent not so much on the total percentage of starch contained as on the relative percentages of starch and protein. The proper proportion of the protein is necessary to hold the starchy mass together when cooked.

[b] Fraser, S., The Potato, New York, 1905, pp. 51–52.

The relation of the maturity of seed to its value has also received considerable attention in Great Britain. Some of the best practical potato growers prefer to have potatoes intended for seed dug before they are fully mature, i. e., while the tops are still green and the outer skin of the tuber rubs up easily. These tubers are then allowed to lie on the ground a short time to "harden" in the light, i. e., to dry and be slightly sunburned, before they are put into storage.

The practice of "boxing" is common and very highly commended. This consists of setting the tubers with "seed end" up in shallow boxes or trays in a dry, light room for some weeks before planting, so as to have strong, short sprouts started upon them. In this way quicker germination, stronger young plants, and a perfect stand are secured.

The general preference in Scotland and in England is for planting small tubers, one and one-half to three ounces, planted whole. If larger tubers are used they are cut, as in this country.

OBSERVATIONS ON POTATO DISEASES AND DISEASE RESISTANCE IN EUROPE.

Insects cause the European potato grower little annoyance or loss as compared with American conditions. Nowhere in Europe, so far as learned, is any use whatever made of insecticides upon potatoes, leaf-eating insects being practically unknown. On the other hand, diseases caused by fungi or bacteria or of nonparasitic origin are even more common and destructive than in America. In the following paragraphs is a discussion of the nature and relative seriousness of such diseases as came under the writer's personal observation, coupled in each case with the evidence secured as to disease resistance. The less important and nonparasitic maladies are discussed first, reserving until later the consideration of the late-blight and rot.

CERTAIN MINOR DISEASES.

INTERNAL BROWN SPOT.

The peculiar disease of the potato called internal brown spot is as well known to plant pathologists and practical potato specialists in Europe as in America. The writer learned nothing more about it on the Continent than is set forth by Frank,[a] who reached only negative conclusions. It is considered not to be a parasitic disease, and no remedy is known and no suggestions are made except the doubtful one of avoiding the use of diseased tubers for seed. In England and Scotland several potato specialists[b] of wide experience gave evidence of like purport. The trouble is frequently observed, and is most commonly termed "sprain." It is not propagated in seed or soil and is nonparasitic. It is considered to be the direct result of malnutrition associated with unfavorable soil conditions, resulting either from too dry conditions or from the lack of potash or lime. It is frequent in light, dry soils during dry seasons, and is never seen on heavy, strong, moist soils. The remedy, in the judgment of the specialists cited, lies wholly in attention to cultural conditions and the choice of varieties.

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[a] Frank, A. B., Kampfbuch gegen die Schädlinge unserer Feldfrüchte, "Buntwerden oder Eisenfleckigkeit," p. 211.

[b] Prof. J. H. Middleton, Messrs. Sutton & Sons, and Thomas A. Scarlett.

Some varieties are more liable than others to internal brown spot and should not be used on soil that favors the disease; e. g., Mr. Scarlett stated that the British Queen variety is especially predisposed to "sprain." The primary remedy, however, lies in selection and treatment of the soil—i. e., in avoiding dry soil—and in so cultivating as to conserve moisture, while using lime and potash liberally.

FILOSITÉ, OR GROWING-OUT.

The names "filosité" and "growing-out" are applied in France[a] and England, respectively, to various forms of secondary outgrowths from tubers. Examples that were shown to the writer were in some cases merely "prongy" tubers, while in others stolons starting from the eyes produced secondary small tubers. Delacroix describes conditions where the seed tubers send out an abundance of weak shoots, both above and below ground, but these soon die without yielding any crop. The latter type is therefore allied to the curl disease of the potato.[b] The less serious forms of growing-out are attributed to climatic and soil conditions, especially to a long, wet autumn following a dry summer. The more serious types of the disease, especially as occurring in France, are attributed to varietal weakness or "running out." In both France and England the use of seed from any plants showing this tendency was condemned as tending to give a crop of generally reduced vitality.

LEAF-SPOT.

Since there has been a difference of opinion among pathologists as to the occurrence and destructiveness of the fungus *Alternaria solani* in Europe, the writer was led to keep an especially close watch for it. Prof. P. Sorauer kindly sent specimens from Europe some years ago corresponding fully with the leaf-spot disease caused by this fungus, and termed early-blight in America. It is known, therefore, that it occurs in Europe, but it can not be as common and destructive as it is here, for no trace of it could be found in any of the fields visited. Much was seen, however, of a leaf-spot disease which bears a superficial resemblance to it. This was shown us first by Dr. Otto Appel in the experimental fields of the board of health at Dahlem, near Berlin. Later it was seen elsewhere in Germany and in England. Apparently there has been a confusion of this with our American early-blight,[a] but both Doctor Appel and Professor Sorauer stated that there was no fungus present in this leaf-spot disease, and the writer's examinations confirmed this. The cause of this trouble has not as yet been clearly established, but since Appel and Sorauer both have it under observation, further advice may be expected upon it in the near future. Opportunity was presented to compare the relative development of this trouble on different varieties in the trial grounds of the University Farm, Cambridge, England, in the latter part of the summer. There was a considerable difference in the amount of spotting of the various varieties, but none was altogether free from it.

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[a] See Delacroix, G., Sur la filosité des pommes de terre, Jour. de l'Agriculture, December, 1903.

[b] Frisolée (French), or Kräuselkrankheit (German), is a common but not very serious potato malady of Europe, of which the cause is not clear, but apparently it is associated with varietal weakness and malnutrition. It is characterized by dwarfish plants bearing an excessive number of rather undersized leaves, which are downcurled and brittle. The tops have thus a dense or bushy appearance. They may be quite as green as normal plants.

SCABBINESS OF TUBERS.

POTATO SCAB.

Scab-like diseases, i. e., those characterized by surface erosions of the tubers, are frequent in Europe and apparently more varied in nature than is recognized to be the case in America. Yet nowhere does injury to the crop from such diseases approach that which is common in this country. This is in some ways surprising and unexplained. A disease closely resembling in appearance the common American type of scab was frequently seen, but growers everywhere in Germany, France, and Great Britain testified that it is not common or destructive enough to be of much practical importance. Scientific men are not agreed either as to the cause of the disease or as to the possibility of benefit from seed disinfection. But few recommended this treatment, and no practical potato grower was met who practiced it. The most puzzling thing, in the light of American experience, is that potatoes are grown year after year continuously or in the shortest of rotations on the same soil without increase of scabbiness. In each of these countries potatoes are often grown on the same soil for ten or twenty or even forty successive years with practically no trouble from scab.[a] Since this is often on rich and heavy land, such as would develop scab under like treatment in America, the European experience is difficult to understand. Does not our type of disease exist there, or is it less virulent because of some difference in the climatic and soil conditions? The writer is not prepared to answer with full confidence, but his judgment favors the second suggestion.

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[a] See Frank, Kampfbuch, p. 220. Apparently the disease mentioned above is the same as Frank's "Pockenfleckigkeit." Frank was altogether mistaken in considering it the same as the American "early-blight," as Sorauer subsequently showed. See also Bahna, J. J., Blattbraune der Kart.; Zeitsch. f. Land. u. Fortwirtsch., 2: 113 (March, 1904). Prof. C. von Tübeuf comments upon this article and reviews the literature in the June, 1904, number of the same journal.

Europeans, both pathologists and practical men, recognize more than one form of disease under the name of scab (the German "schorf," Dutch "schurft," French "la gale"). Frank's subdivisions[b] of "schorf" into four kinds—flach, tief, buckel, and buckel-tief schorf—were familiar to the continental pathologists interviewed, but the general opinion is that these are simply forms of one common disease, the variations being attributable to the season of attack or to varietal or vegetative conditions of the potato. Frank's specimens of "tief-schorf" were seen in the museum of the board of health at Berlin and have the appearance of the common American scab.

As to the cause, opinions differ.[c] The German pathologists who have given most attention to this disease consider the commonest German form to be due to a fungus similar to Thaxter's *Oospora scabies*, but perhaps not identical with it. In Holland doubt was expressed as to the common Dutch form of potato scab being a fungous disease at all, while in Belgium and France it is considered a parasitic disease, but due to bacteria (*Micrococcus pellicidus* Roze) rather than to fungi.[d] In England *Oospora scabies* is held responsible for only the minor part of the trouble, *Sorosporium scabies* Fisch. being the commoner parasite.

VARIETAL RESISTANCE TO SCAB.

As already stated, none of these scab diseases has proved of sufficient economic importance to attract much attention from practical potato growers in Europe. Probably most of the diseases would yield to the seed-disinfection treatment practiced for potato scab in America, yet this is nowhere used by European growers, so far as learned. The only valuable data as to the relative susceptibility of varieties to scab are those furnished by the reports of Professor Eckenbrecher,[e] whose results point to certain newer varieties as being comparatively free from scab, while others are quite susceptible. Age of the variety, however, seems to be of less consequence than it is with the blight, for while one of the least resistant is Dabersche, an old standard, one of the most resistant is Richter's Imperator, also an old variety. Other varieties reported as preeminently scab resistant are Irene and Professor Wohltmann. Boncza and Pomerania are reported resistant, but to a less degree. Seed of all these have been secured for trial in this country. Early Rose is found especially liable to scab there as it is in America. It will be better, however, to postpone the discussion of resistance to scab as shown by American varieties of potatoes until the latter part of this publication.

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[a] See Sutton, A. W., Potatoes, Jour. Roy. Soc., XIX, pp. 387–430 (1896).

[b] Kampfbuch, p. 170.

[c] These conclusions are the result of conferences with a number of men and reference to the publications of others. Among those who have given this disease careful consideration in their respective countries and whose opinions were learned are Professors F. Krüger, Berlin; Ritzema-Bos, Amsterdam; Marchal, Gembloux; Roze and Delacroix, Paris; Massee and Cooke, England.

[d] Roze, E., Histoire de la pomme de terre, Paris, 1898, p. 275.

[e] C. von Eckenbrecher, Berichte Deutsch.-Kart.-Kult.-Stat., 1903 and earlier.

OTHER SCAB-LIKE DISEASES.

Rhizoctonia.—This was seen on potato tubers in Europe even more commonly than it occurs in America, but most European pathologists regard it as nonparasitic. Those who consider it as a facultative parasite attribute little injury to it generally, although some think it capable of causing rot, as described by Frank.[a]

Spongospora solani Brun.—This fungus is said[b] to cause a scab-like disease in the north of Europe. This disease occurred[c] to a considerable extent on potatoes secured by the writer's order from Groningen, Holland.

Superficial scurvy diseases attributed to other fungi occur in Europe. Frank[d] describes one such caused by *Phellomyces sclerotiophorus*, but Doctor Appel told the writer that this had not proved serious in Germany. Johnson[e] reports it as causing some trouble in Ireland. In England another scurf disease of somewhat similar appearance is attracting attention. It occurred on the Eldorado seed potatoes imported with our order from Scotland, and the cause is apparently the fungus *Spicaria nivea* Hors.[f]

Oedomyces leproides Trabut.—This is a fungus[g] which attacks the young sprouts or eyes of the tubers, stimulating them to abnormal, cauliflower-like growth, of which the dark color has given rise to the popular name black-scab. The writer did not see this disease on the

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[a] Kampfbuch, p. 194.

[b] Ibid., p. 176.

[c] Found and identified by James Birch Rorer.

[d] Kampfbuch, p. 182.

[e] Johnson, T., The Diseases of the Potato and Other Plants in Ireland, Journal, Dept. Agric. Ireland, Vol. III, No. 1 (1902).

[f] So identified by Dr. Ernst A. Bessey. Dr. Thomas Milburn, of the Midland Agricultural and Dairy Institute, England, advises the writer by letter that he is engaged in a special study of this disease. He finds it to occur on most English varieties, Evergood and Sutton's Flourball being by far the worst, while East Anglian and Sutton's Discovery are the only ones he has found entirely free from it.

[g] This also occurs on beet roots. See Massee, Geo. A., Textbook of Plant Diseases, p. 225.

Continent, but while in England Dr. M. C. Cooke sent specimens, as did also Dr. John Wilson, from Scotland. It is regarded as capable of causing much harm, but fortunately has not as yet become common.

POTATO STEM DISEASES.

BLACKLEG.

"Schwarzbeinigkeit," or blackleg, is a name applied to a disease seen commonly in central Europe. It is characterized by the blackening and rotting of the main stem, accompanied by a checking of the growth, uprolling, yellowing, and ultimate death of the leaves, and more or less rotting of the tubers. It has been exhaustively studied in recent years by Appel[a] in Germany, who concludes that it is due to bacteria (*Bacillus phytophthorus*, and perhaps other allied species). which either enter from the soil or are carried in the seed tuber. These start the disease below ground, the rot proceeding, as a rule, from the seed tuber to the young plant. Appel's conclusions are generally accepted by pathologists in Germany, Holland, and Belgium, and, so far as learned, in England.

The writer had opportunity to see much of the German disease in the vicinity of Berlin, and to verify Doctor Appel's observations, in a measure, in his own laboratory. Later (August) the same malady was seen in England, where it is said to be common, though apparently less troublesome than Appel reports it from Germany. All of the personal observations of the writer therefore lead to an indorsement of Appel's conclusions both as to the bacterial nature of the disease and as to its widespread occurrence and economic importance.

In France a similar if not identical disease is attributed to bacteria. Delacroix, who has studied this, considers the organism causing the disease, which he calls *Bacillus solanicola*, to be specifically distinct from that described by Appel. He kindly showed the writer specimens of the French disease in his garden in Paris, but it was in a stage so much more advanced than that seen in Berlin that a comparison of the two does not seem justifiable.

Of course, the possible occurrence of these stem diseases in America was kept in mind. The writer has never seen much, if any, of the same trouble in potato fields in the Northeastern States and adjacent Canada which have come under his observation. Certainly it is not so common in America as it is in Europe. The symptoms correspond, however, somewhat closely to certain diseases attributed to Rhizoctonia in the South and West.[b]

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[a] Appel, O., Arb. aus Biol. Abt. Gesundheitsamte, 3: 364 (1903).

[b] See especially Selby, A. D., Ohio Exp. Sta. Buls. 139 and 145, and Rolfs, F. M., Colo. Exp. Sta. Buls. 70 and 91.

The only remedies proposed or practiced for blackleg in Europe consist in selection of sound seed, careful avoidance of rotten tubers or those taken from a diseased crop, attention to rotation of crops, since the germs may persist and accumulate in the soil, and the use of disease-resisting varieties. None of these methods has been tested carefully enough to establish its merits.

The chief evidence as to varietal susceptibilities or resistance to blackleg is that of Appel.[a] He states that while no varieties have been shown to be entirely free from the disease, the evidence is that thick-skinned, starch-rich, late varieties are in general more resistant than thin-skinned, starch-poor, early varieties. The Dabersche he finds to be the most resistant of the widely used German sorts, while the Rose varieties are especially liable to blackleg. Contiguous plats of the Dabersche and White Rose in Doctor Appel's grounds showed this difference very clearly at the time of the writer's visit in July, 1904, the Rose being badly diseased, the Dabersche but slightly. At the Deutschen-Kartoffel-Kultur-Station distinct evidence of variations in disease resistance was found. It was stated at this station that in the trial grounds the red varieties were in general found to be more resistant than the white.

A considerable development of this disease was noticed at the University Farm, Cambridge, England, where extensive variety trials were being conducted. The observations of Mr. H. Henshaw, who had immediate charge of these, were in agreement with those of Doctor Appel as to the association of the disease with the rot of the seed tuber, and he regarded it as a bacterial malady. There was a difference in the amount of the disease on different varieties, but Mr. Henshaw found none wholly free from it. At the time of this visit Factor and Up-to-Date were noticeably freer from the trouble than any other varieties there under trial. They were about alike in this, as, indeed, in all other characters. Doctor Delacroix cited as especially resistant to his bacterial disease in France the variety La Czarine. He also stated that the variety Geante Bleue is resistant, but to a less degree. Laurent observed in his work on bacterial diseases that the maximum of resistance was shown by the varieties Chardon, Pousse-debout, and Chave.

OTHER STEM DISEASES.

Several other potato stem diseases have been reported in Europe, but since the writer did not study them in the field and learned nothing beyond what is recorded in literature they will be passed with brief mention. Prillieux and Delacroix have described another bacterial stem disease in France attributed to *Bacillus caulivorus*. Rhizoctonia is common on potato stems as well as tubers, but none of the pathologists conferred with regards it as a parasite of importance on either. Professor Marchal, of Gembloux, said, however, that he sometimes found a basidiomycetous fungus, *Hypochnis solani* Prill.,[a] causing a blackleg-like stem disease in Belgium. Prof. T. Johnson, of Dublin, sent specimens of *Sclerotinia sclerotiorum*, which at times causes a destructive stem disease in Ireland, called "yellow blight." He also reports[b] the occurrence in Ireland of bacterial stem diseases, including what he believes to be the malady termed brown-rot in America and shown by Dr. Erwin F. Smith to be caused by *Bacillus solanacearum*. In none of these cases was anything learned as to relative varietal resistance to the disease in question.

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[a] Arb. aus Biol. Abt. Gesundheitsamte, 3: 408 (1903).

LATE-BLIGHT AND ROT DUE TO PHYTOPHTHORA INFESTANS.

Late-blight and rot due to *Phytophthora infestans* occurs in Europe even more widely and destructively than in America, being recognized as the most important malady in all the countries visited by the writer—Italy, Austria, Germany, Holland, Belgium, France, and the British Islands. There was less unanimity of opinion than was anticipated as to the probable life history of the fungus, and consequently as to the remedial treatment. While all agreed that it lives over in the seed tubers, the opinion was frequently expressed, by scientific and practical men alike, that there is probably some hibernation in the soil, either in tubers left in the field or in the haulms. Possible hibernation in the tubers is to be associated with the fact that potato tubers left in the soil are not killed by frost in southern England and the south of Europe. The value of Bordeaux mixture as a remedy is recognized generally. Spraying is consistently advocated and practiced in the British Islands—especially Scotland and Ireland—the Netherlands, Italy, and portions of France. Germany has been surprisingly backward in accepting or even fairly testing this remedy. The reason seems to be that some of the experiments conducted by scientific men have shown injury to the plants, and so they have pronounced against it. No other remedial treatments are in common use. No one indorsed or practiced any method of seed disinfection. No particular culture methods were advocated or condemned other than attention to fertilization. There was a general agreement that excessive use of nitrogenous fertilizers, either chemicals or composted manures, increases the loss from this disease. Much attention is being given, however, to the relation of varieties and of source of seed to disease resistance, and the results are of sufficient importance to merit the somewhat detailed report which follows.

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[a] Probably identical with *Corticium vagum* var. *solani* Burt, which is the fruiting stage of the common Rhizoctonia of the potato.

[b] Johnson, T., Diseases of the Potato and Other Plants in Ireland, Journal, Dept. Agric. Ireland, III, No. 1 (1902)

RESISTANCE AS SHOWN TOWARD LATE-BLIGHT AND ROT.

HISTORICAL STATEMENT.

Doubtless examination of the earlier writings upon the potato disease known as late-blight and rot would show that from the beginning of its ravages differences have been observed in the resistance of varieties. Any such records of the thirty years from 1845 to 1875 would have no practical value now, since the varieties then in use have passed out of culture; nor would they have much scientific significance, owing to the lack of exact knowledge then as to the cause of disease. Going back to the origin of the varieties still in cultivation, it is found that in the early seventies an unusual amount of attention was focused upon the matter of the potato disease, as to causes and remedies. Ninety-four essays secured by the Royal Agricultural Society of England in 1872 showed agreement that an underlying cause was the degeneracy of the varieties then in culture.[a] The necessity for the production of new varieties was emphasized. The introduction of improved American varieties into England at about this period was most beneficial and stimulating to the potato specialists of that country.[b] These varieties were made the parents in further breeding. The best production of this revival was the Magnum Bonum, originated by James Clark from a cross of Early Rose with Victoria and introduced by Sutton in 1876. Experience with this variety laid the foundation for belief in possible disease resistance in potatoes both in England and on the Continent. Magnum Bonum soon became the standard main-crop variety of Great Britain and so continued until within the last fifteen years, when it yielded to Up-to-Date and others. It is still in considerable favor on the Continent.

Charles Darwin in 1877–78 became interested in the possibilities of disease-resistant breeding. Francis Darwin[c] states that Mr. James Torbitt, of Belfast, bred and selected varieties to secure disease resistance, his method being to cross-fertilize, rear the seedlings, and expose them ruthlessly to infection, retaining only those showing some degree of resistance. In this work he received much encouragement and some financial aid through Charles Darwin.

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[a] See Jour. Roy. Agr. Soc. Eng., XX : 291 (1884).

[b] Dean, A. Potato Improvement in the Past Twenty-five Years. Jour. Roy. Hort. Soc., XII : 41 (1890).

Mr. C. G. Pringle, who was then the foremost potato breeder in America, states that the demand from Europe for new American varieties was very active at that period, and continued until the fear of the Colorado potato beetle led to the prohibition by European governments of further importations of potato tubers from America. Thereupon Mr. Pringle supplied B. K. Bliss & Sons with specially hybridized potato seed, which was sent abroad in considerable quantity.

[c] Life and Letters of Charles Darwin, II, pp. 519–522.

The writer learns from Prof. T. Johnson, of Dublin, that Torbitt has been dead some twenty years. He was in the wine trade and raised varieties of potatoes for the berries, or seed balls, which he used as a source of material for wine. All of his varieties have disappeared except one coarse, red one, which was and is proof against disease.

A committee of the English House of Commons, reporting in 1880 upon the potato disease, found all its witnesses concurring in the necessity for the production of new varieties with increased disease resistance.[a] Parliament was asked to give financial aid for experiments aiming to produce new and disease-proof varieties, but it did not do this. Earl Cathcart, in commenting on this report, states that—

> All potatoes have deteriorated in their disease-resisting powers. A variety from seed takes four to six years for its establishment, and under the most favorable circumstances a good variety might be expected to degenerate in twenty years. The production of new varieties is of national importance.

Apparently through the influence of Cathcart, Baker[b] was led to make an exhaustive comparative study of the genus Solanum in order to advise as to the relation of the cultivated varieties to the several wild species of the American continent preparatory to breeding experiments in which these might be used. As a result, two species were considered worthy of further trial in the attempt to improve disease resistance, viz, the Darwin potato, *S. maglia*, from the Chonos Archipelago, and the Uruguay potato, *S. commersonii*. Cathcart furnished Sutton with the former and he hybridized it with the common *S. tuberosum*. Sutton[c] reports that, beginning in 1886—

> Although many hundreds of flowers of *S. maglia* were artificially fertilized with pollen from cultivated varieties, only five were successful, resulting in five berries. From these but two seedlings were secured and only one of these showed any promise whatever, the second having to be grown under glass to prevent its dying. * * * This hybrid, although a vast improvement on *S. maglia*, is far behind the ordinary potato in appearance, crop, and quality. The seedling * * * grown for eight years, in 1894 was slightly diseased, although previously free from attack.

Sutton still has the *S. maglia* and this hybrid in propagation at Reading, where the writer saw them in August, 1904. Phytophthora was then more rampant on the foliage of both of these and on *S. commersonii*, which he also has, than on the average potato plants in his fields. No hybrids of *S. commersonii* had been secured by him previous to this. Mr. Lasham, potato specialist for the firm, has been giving renewed attention to the possibilities of species hybridization, and showed the writer balls which he considered to contain hybrid seeds of *S. tuberosum* × *commersonii*.

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[a] Jour. Roy. Agr. Soc. Eng., XX: 291 (1884).

[b] Baker, J. G., A Review of the Tuber-Bearing Species of Solanum. Jour. Linn. Soc., London, XX, 489–507 (1883–84).

[c] Sutton, A. W., Potatoes, Jour. Roy. Hort. Soc., XIX, 387 (1896).

Interest in the possibilities of *S. commersonii* has recently been stimulated by the experiments inspired in France by Prof, E. Heckel.[a] who believes in the economic possibilities of this species when improved by longer culture and perhaps by hybridizing, and has distributed it quite widely in France with this end in view. One French horticulturist, Labergerie,[b] claims already to have succeeded in producing a variety of edible quality, large yield, and superior disease resistance. This was seen growing in the grounds of Vilmorin-Andrieux & Co., at Paris. This firm was not yet convinced of the practical value of the plant, and since Labergerie refuses to send out any of these potatoes for trial at present, judgment must be reserved.

Returning to the consideration of the varieties of the common potato, it is found that during the last decade increasing attention has also been given to their comparative disease resistance. This has been well summarized by Prunet.[c] The main facts developed are as follows: Sorauer[d] in 1896 considered the evidence to date as showing that the highest degree of disease resistance was possessed by Magnum Bonum, the following showing some degree of resistance: Blaue Riesenkartoffel, Richter's Imperator, Athene, Reichskanzler. Rostrup,[e] writing about the same time from Denmark, places Magnum Bonum at the head as a disease-resisting variety, with Richter's Imperator and Champion as somewhat resistant.

In this connection it is noteworthy that Magnum Bonum has yielded its place in popular favor in Great Britain for main-crop purposes to Up-to-Date and other varieties, even while holding its reputation on the Continent. During the last decade these standard varieties in turn have been "running out," and the demand in England for something to take their place has stimulated potato breeders and seed specialists to direct their attention very generally to the development of a disease-resisting main-crop variety. The greatest efforts in breeding have been made during the last four years, while speculation in the most promising of the varieties produced has been at fever heat for the last two years, during which time many new varieties, more or less disease resistant, have been pushed to the front. There are now so many potato specialists in Great Britain breeding and handling varieties of reputed disease resistance that it is impracticable to mention all. Archibald Findlay, of Mairsland, Auchtermuchty, Scotland, has originated some varieties of high repute; Sutton & Sons, of Reading, England, have also taken a prominent part in this work. Scotland-grown seed of all the leading varieties can be secured from Thomas Scarlett, of Edinburgh, and Mr. Scarlett has some promising varieties of his own introduction. Anyone desiring more specific information should secure the publications of the National Potato Society from its secretary, Walter P. Wright, Postling Vicarage, Hythe, Kent, England.

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[a] Heckel, E., Sur le *S. commersonii*, Rev. Hort. de la Soc. d'Hort. et de Bot. des Bouches-du-Rhone, No. 581, pp. 200–206 (December, 1902); also, Contrib. à l'étude botanique de quelques solanum tuberiferes, Ann. de la Faculté des Sciences de Marseille, vol. 8 (1895).

[b] Labergerie, M., Le *Solanum commersonii* et ses variations, Bul. Soc. Nat. d'Agric. de France, March, 1904.

[c] Prunet, A., Le mildieu de la pomme de terre, Rev. de Viticult., XVII, 663; XVIII, 97 et seq. (1902).

[d] Zeitsch. f. Pflanzenkr., VI, 284 (1896).

[e] Tidsskrift f. Landbrugets Planteavl, 1895, 1896, 1897.

Meanwhile the German Potato Station has been making extensive tests, doing some breeding and encouraging several potato breeders.[a] These efforts have not been directed primarily to disease resistance, but the station has taken note of this feature and published the data regarding all varieties tested.

While the results of this work in Europe have been collected or correlated by no one, the writer was able to gather considerable information, in addition to that already referred to, from conversation with potato specialists, especially in Great Britain. This, together with what has been learned in America, is made the basis of the following discussion. It is to be regretted that it is impracticable to give detailed credit in some cases to those who kindly furnished the information.

THE MEANING OF DISEASE RESISTANCE.

Although potato specialists, especially in England, apply the term "disease proof" to their favorite varieties, this is not to be taken literally. No variety has as yet shown itself to be absolutely proof against disease. The writer personally collected leaves infected with the blight fungus from two varieties which were said to be "disease proof." Absolute resistance against the blight fungus has not as yet been and may never be secured. Varieties are known, however, which show a relatively high degree of disease resistance. This may be shown in the delay in date of appearance of the blight on the leaves or its slower progress after appearing, and still more clearly in the relatively small amount of loss from rot of the tubers. Most of the exact observations made in Europe have been based on this latter difference.

DISEASE RESISTANCE AND VEGETATIVE VIGOR.

Disease resistance and vegetative vigor are closely associated, although the factors involved are not necessarily identical. In any consideration of the problems of the life and death of the potato plant it must be remembered that the potato has two natural methods of reproduction, the true seed produced in the berries or "balls" following the blossoms, and the tubers produced below ground. Reproduction by seed is a sexual process, that by tubers is vegetative. Both are exhaustive of vitality. The two are in a certain sense physiologically opposed to each other and can not well be carried on at the same time by the plant. Under the natural conditions of the wild potato plant in Mexico, and doubtless elsewhere, seed production precedes tuber formation. In Europe and northern America, with a shorter season and intensive culture, the two processes overlap. As a result there is, just after the potato plant comes into blossom, a period when the natural tendencies within the plant toward seed production above and tuber formation below are such as to subject it to unusual physiological stress. This has been termed the "critical period"[a] in the development of the potato plant.

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[a] The most active of these are Paulsen, Cimbal, Richter, and Dolkowski. Graf Arnim-Schlagenthin, of Nassenheide in Pommern, is an extensive breeder and dealer in new varieties, as is also F. Heine, of Hadmersleben.

Usually the blossoms fall without the setting of the fruit, and the plant then passes into a stage where its energies are devoted to tuber formation alone. Once well started upon this vegetative period, its growth is more or less indeterminate, i. e., there is no clearly defined natural terminus to the life of the cultivated potato plant. Instead, there is the gradual decline in vegetative vigor which may prepare the way for early-blight and other diseases characteristic of weakling plants. It is noteworthy that the destructive attacks of the late-blight fungus occur, as a rule, after the blossoming period has passed. So far as the evidence goes it seems to suggest that high vegetative vigor enables the plant to ward off in some degree the fungus attack.

There is, moreover, a natural decline in vigor, or "running out," with the age of the variety. The length of life of a variety depends upon numerous conditions, and is an indefinite matter in any case. It is ordinarily placed by potato specialists at from twelve to twenty years. As a variety begins to "run out" it apparently shows, among other things, a lessened degree of general disease resistance. Thus Magnum Bonum had the highest reputation in this respect from its origin in 1876 until about 1890 in Great Britain. On the Continent it has remained longer in favor. Up-to-Date has held a like place during the last decade in Great Britain, and Richter's Imperator has a similar record in Germany. These statements are based upon the popular verdict, not upon exact experiments; but the belief that disease resistance decreases with the age of the variety is firmly established in the minds of specialists in potato culture in Great Britain, at least so far as concerns resistance to Phytophthora.

There is little definite evidence regarding the relation of vegetative vigor to resistance to other diseases, but so far as it is formulated it favors the general applicability of the idea. The production of berries, or seed balls, is held by some English breeders to be an indication of such vigor, and therefore presumably of disease resistance, although no one claims that the absence of these is equally strong evidence in the opposite direction. It is worthy of passing note that berries are formed much more commonly in Europe, especially in Germany and Holland, than in America, apparently because of climatic differences.

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[a] See Jones, L. R., Certain Potato Diseases and Their Remedies, Vermont Exp. Sta. Bul. 72: 4 (1899); also The Diseases of the Potato in Relation to Its Development, Trans. Mass. Hort. Soc. (1903), Part I: 144.

THE RELATION OF HYBRIDITY TO DISEASE RESISTANCE.

By a "new variety" of potato, as the term is commonly used, is meant one recently developed from the seed. Sports may appear and are indeed frequent in some varieties. These will, however, be mentioned later. The seed in all cases presumably represents a sexual origin, i. e., comes from a fertilized flower, but this may have been either self-fertilized or cross-fertilized. One would expect greater vigor to result from the cross-fertilization, and potato breeders are of the opinion that it is secured. On the other hand, while varieties recently originated from seed may show a high degree of disease resistance, this is not necessarily the case according to the verdict of English and German breeeders, many new varieties proving as susceptible as old ones.

Reference has already been made to the work of Cathcart and Sutton in England and of Heckel and Labergerie in France based on the hope of advantage from using one or another of the wild Solanums for such hybridizing. There are interesting possibilities along this line, since there are many wild forms of *S. tuberosum* in addition to other species of tuberiferous Solanums. Thorough trials of these are now being made by Stuart[a] at the Vermont Experiment Station which will be reviewed later in this paper. It should be emphasized at once, however, that while the use of the wild Solanums does offer interesting possibilities, there is no record of practical success from their use, if we except the doubtful one of Labergerie's variety of *S. commersonii* previously referred to. On the other hand, great practical improvements have been secured by various breeders from crossing varieties of cultivated potatoes.

IMPROVEMENT BY SELECTION.

All plants tend to vary. One of the commonest ways to improve plants is by selection from among the varying individuals. For the first two years after their origin, variants, or "rogues," are not uncommon with the seedling potato, but the variety is "fixed" by the weeding of such rogues before it is distributed for general culture, and thereafter very little variation occurs. Some modification is to be expected, nevertheless, and among other things there may be variation in disease resistance. It seems worth while, therefore, to keep a lookout for individual plants which show especial resistance to the blight when this is epidemic about them. The tubers of such individuals deserve to be carefully saved apart and planted, in order that it may be seen whether their resistance is a fixed and inheritable character or the result of some chance difference in environment. Such selection has already been undertaken by three persons to our knowledge: Appel in Germany,[a] Stuart in Vermont,[b] and Fraser in New York;[c] but no practical results have as yet been secured.

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[a] Stuart, W., Disease-Resistant Potatoes, Vermont Exp. Sta. Bul. 115 (May, 1905).

ARE EARLY OR LATE VARIETIES THE MORE RESISTANT?

The blight never becomes serious until the midseason of potato growth is passed; thus in our Northern States its worst ravages come in August and September. Therefore early varieties, as a rule, escape. But this is simply because they mature before the blight is epidemic. So far as evidence has been secured, both in America and Europe, when the early varieties are planted late enough to expose them to the disease alongside of the later ones, the early varieties as a class suffer the worst. For example, the most complete destruction by rot which the writer ever saw was with a late crop of Early Ohio potatoes attacked by the disease in September. Woods,[d] of Maine, has also found early varieties especially susceptible.

RELATION OF SOURCE OF SEED AND CULTURAL METHODS TO DISEASE RESISTANCE.

The opinions of highly intelligent potato growers in Great Britain are especially worthy of note. One of the first concerns with them is the source of their seed. Mention has already been made of the experiments at Sutton's grounds, showing the superiority of northern-grown seed. It was found to be the general verdict of practical men in Europe that northern-grown seed is more highly disease resistant, as well as more productive. If one is to aim for the best results in health of crop, therefore, attention should be directed to quality and source of seed as well as to variety.

Practical men as well as scientists generally agree that methods of culture also determine to a considerable degree liability to disease. These act not only indirectly as they affect moisture content or other physical conditions of the soil, but more directly as they affect the vigor or inherent disease resistance of the plant itself. Seed dealers in this country, as well as in England, have also expressed a preference for seed from a crop that has not been very highly fertilized, especially with nitrogenous manures. The most detailed study along this line is that of Laurent,[a] whose results indicate that nitrogenous fertilizers predispose both the foliage and the tubers of the plants to the attacks of Phytophthora. This is in harmony with the general opinion of practical potato growers, that high manuring increases the liability to disease.

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[a] Appel, Otto. Die diesjährige Phytophthora-epidemie, Deutsche Landw. Presse, XXIX: 685 (1902).

[b] Vermont Exp. Sta. Bul. 115, p. 139.

[c] Reported in correspondence.

[d] Woods, C. D., Maine Exp. Sta. Rpt., XIX: 181 (1903).

COMPOSITION AND CHARACTER OF TUBERS AS RELATED TO ROT RESISTANCE.

There is considerable evidence that the chemical composition of the tubers bears a direct relation to resistance to rot. Paulsen[b] claimed that varieties rich in nitrogen compounds are less resistant to disease than those rich in starch. He classed most of the early varieties in the first category and found the larger percentage of the second class to be of the late varieties. The table varieties of better quality were also of the first category.

Petermann[c] has recently made field and laboratory studies at the Belgium Experiment Station. These led him to practically the same conclusions, viz, (1) that varieties richer in amids are more liable to rot, although of superior table quality; and (2) that varieties relatively richer in starch, including several recently originated German factory varieties, are less liable to rot but are of inferior quality for table use.

Sorauer[d] has published similar conclusions, and he made more detailed statements as to his belief on this point in conversation last summer. In general, he believes that the varieties richer in protein are more liable to disease, while those richer in starch are more resistant. This probably explains his observation that the yellow-fleshed varieties, which are in higher repute in Germany for table use, are more liable to disease[e] than the white-fleshed varieties which are grown for factory purposes. His further observations in harmony with this idea are that the thicker and rougher skinned red varieties[f]—e. g., Dabersche—have a higher degree of disease resistance, coupled with relatively high starch and low protein content, whereas the thin-skinned white varieties, which are more liable to the disease, have proportionately less starch and more protein. As a rough empirical test he considers that if, when a fresh tuber is cut open, the flesh browns quickly on exposure to the air and the vascular bundles darken soon, it is evidence of high protein content, and therefore of liability to disease, whereas the reverse condition is evidence of probable disease resistance. Professor Sorauer also emphasized to the writer his belief in the relation of soil, manuring, or other cultural condition to disease resistance. The testimony secured elsewhere in Germany, as well as from American sources, is in harmony with these ideas so far as it goes.

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[a] Laurent, Recherches exp. sur la mal. des plantes, Ann. Inst. Past., XIII, pp. 1–48 (1899).

[b] Biedermann's Centralbl. Agr. Chem., 1887, p. 107.

[c] Bul. Inst. Chim. et Bact. Gembloux, 70 (1901).

[d] Jahresber. d. Sondersaussch. f. Pflanzensch., XII and XIII (1902 and 1903).

[e] See evidence of this also in Jahresber. d. Sondersaussch. f. Pflanzensch., XIII, 1903.

[f] See also statement that red varieties are in general more resistant; Jahresber. d. Sondersaussch. f. Pflanzensch., XII, 1902.

While character of skin is probably a less reliable index to rot resistance than is chemical composition, yet the writer has learned of several potato experts in America, as well as others in Europe, who regard the red varieties, especially such as have a rough skin, as less liable to rot than are the white thin-skinned varieties. The Dakota Red has often been cited as an example of this class in America. Abundant evidence can be found, however, especially from English experience, of high disease resistance coupled with a thin, white skin. Breeders aiming at disease resistance need not turn from the white-skinned varieties.

CHARACTER OF STEM AND FOLIAGE AS RELATED TO DISEASE RESISTANCE.

In connection with the question of the relation of the character of the stem and foliage to disease resistance it is not safe to go far in generalizing. Mr. Lasham, potato expert and breeder with Sutton & Sons, considers that a stem that is strong, rough, and hard, almost woody at the base, is an important character if the plant is to be most highly disease resistant. The nature of the foliage is considered by others to be of greater importance, the preference being for small leaflets, rough and relatively thick rather than large and flabby. A rich dark-green is preferred to the lighter colored foliage. It seems inherently probable that the character and color of foliage should stand in close relation to the other matters which have with more certainty been shown to be related to disease resistance, viz, general vigor and capacity for starch manufacture. Those giving further attention to disease resistance may, therefore, well bear these suggestions in mind.

DISEASE-RESISTANT VARIETIES OF EUROPE.

When all the factors are considered, two important things become evident: First, that no variety will maintain its disease-resistant qualities indefinitely, losing them sooner in one locality than in another; second, that no one variety will be equally disease resistant in all countries, i. e., what is best suited to one may not be to another.

Hence we must expect much conflicting evidence regarding the same variety, especially as grown under different conditions and in different countries.

The most satisfactory way will be to summarize separately the evidence obtained in each country visited in Europe, followed by that from America.

The greatest activity in breeding for resistance occurs in Great Britain, and next to this in Germany, while France has recently shown special activity in one line. There were secured from each of these countries all the varieties of especial promise for trial in America—comprising a total of nearly one hundred. By no means all of these have an established reputation as being highly disease resistant, although all will be tested for this as well as other characters.

Experience has shown that the transference of a variety from Europe to America, or the reverse, is likely so to disturb the equilibrium of the plant that the developments of the first year are scarcely normal. At least two years are necessary for the adequate testing of imported varieties. Commercial growers should therefore make only trial plantations of any European variety until its adaptability to American conditions has been proved. Seed of the varieties secured will be under trial at several points this season and next. While it does not seem worth while to publish the full list of these in advance, the following are selected as representing the varieties or types most strongly indorsed in their respective countries for disease resistance.

GREAT BRITAIN.

More attention has been given to this question in Great Britain than anywhere else. Careful comparative observations are recorded as to the relative disease resistance of all the leading varieties. The last report of the National Potato Society specifies the following eight varieties as the best for disease resistance, named in the order of their merit. The writer appended certain facts as to the origin and characters of each. All are white skinned, white fleshed, of excellent quality, of high general vigor, and heavy yielders.

TABLE I.—*The most disease-resistant varieties of potatoes in Great Britain, as announced by the National Potato Society.*[a]

Order of merit.	Name of variety.	Originator.	When sent out.	Season.
1	Evergood	Findlay	1896	Medium late.
2	Discovery	Sutton	1903	Late.
	Royal Kidney	Findlay	1896	Second early.
3	Northern Star	do	1901	Late.
4	Sir John Llewelyn	Harris	1900	Early.
5	King Edward VII	Butler	1901	Medium.
6	Eldorado	Findlay	1903	Medium late.
7	Factor	Dobbie	1898	Late.

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[a] Annual Report, National Potato Society, I: 36 (1904).

Two points brought out by the foregoing table are worthy of especial note: First, the remarkable success of one man in producing four of these eight varieties, showing that there is something more than chance in their development; second, the comparatively recent origin of all. For the latter fact there is probably a double explanation: (1) The loss of disease resistance with age of the variety; (2) the remarkable activity of British potato breeders during the last few years, with the aim above all else of securing increased disease resistance.

It should be remarked that there are a number of more recent introductions which promise to rank with the best of these varieties, but they have not as yet been so fully tested.

GERMANY AND HOLLAND.

The potato-growing industries of Germany and Holland have much in common, and similar or identical varieties are used. Data were not available for making so definite a selection as in Great Britain. The following are probably representatives of the highest grade of disease resistance achieved:

TABLE II.—*The most disease-resistant varieties of potatoes in Germany and Holland.*

Name.	Originator.	Season.	Color of skin.
Mohort	Dolkowski	Late	White.
Irene	Paulsen	Medium late	Red.
Geheimrat Thiel	Richter	do	White.
Professor Wohltmann	Cimbal	Late	Red.
Boncza	Dolkowski	Medium late	Do.
Eigenheimer	(Holland)	Medium early	White.
Paul Krüger	do	Late	Do.

The first five varieties have been imported from Germany. All of these are of the white-fleshed, starch-rich type which is being developed there primarily for factory rather than for table use. They are, however, reputed to be of fair quality except, perhaps, in the case of Irene. These, like the British varieties, are of comparatively recent introduction.

The Holland varieties are of a similar type except that Eigenheimer has a yellowish-tinted flesh.

FRANCE AND BELGIUM.

The conditions are similar in France and Belgium. Neither country has varieties of much promise for trial in our Northern States. In Belgium the varieties recommended as being most highly resistant to blight and rot were the recently originated German factory types like those already mentioned, to which might be added Topas and Professor Maercker. The verdict in France was similar, Professor Maercker again being commended, along with the English varieties

Magnum Bonum and Royal Kidney. The indorsement of these comparatively late, white-fleshed, starch-rich potatoes in France and in the other continental countries is the more significant when one remembers that the chief aim with potato specialists there is to produce the yellow-fleshed potato rich in protein.

DISEASE-RESISTANT VARIETIES OF AMERICA.

Until two or three years ago no systematic attempt was recorded, so far as the writer has learned, to determine the relative resistance to blight and rot of potato varieties in America. Of course this would not imply that individual growers have not observed these differences, but they are rarely matters of record, and as a rule are based only upon limited observations. Only two or three potato-seed dealers are advertising disease-resisting varieties with any prominence this year, and these are in all cases comparatively new and little-tried sorts.

INVESTIGATIONS AT THE EXPERIMENT STATIONS.

Promising investigations have been inaugurated at several of the State agricultural experiment stations which should soon supply data for more reliable conclusions than are now possible. Woods,[a] of the Maine station, and Green,[b] of the Minnesota station, have each reported results of variety trials as to disease resistance.

Woods found a marked difference in the ability of varieties to withstand both blight and rot. As a rule the earlier varieties were soonest attacked. The variety Rustproof showed the highest degree of foliage resistance and also the least rot, viz, only a little more than 1 per cent, whereas the average of all varieties under trial was more than 30 per cent.

Green found that the loss from rot varied widely with varieties, ranging from 1 per cent in the most resistant to 40 per cent in the least resistant types. Potatoes of the type of Sir Walter Raleigh and Rural New Yorker resisted rot better than those of any other class. Of the 49 varieties tested, only two, Clay Rose and an unnamed seedling, were practically free from rot. These trials will be continued.

Observations on disease resistance have also been made by Macoun at the Central Experimental Farm, at Ottawa, Canada. He has kindly advised the writer, in correspondence, of his conclusions. The following varieties have shown especial disease resistance as judged by appearance of blight on the foliage: Holburn Abundance and Professor Maercker are most resistant, with Swiss Snowflake, State of Maine, and Rural Blush only a little less so.

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[a] Woods, C. D., Maine Exp. Sta. Report, XIX: 181 (1903).

[b] Green, S. B., Potatoes at the University Farm, Minn. Exp. Sta. Bul. 87 (1904).

WORK AT THE VERMONT STATION.

The most extensive work on potatoes has been done by Stuart, who two years ago inaugurated at the Vermont station variety trials as to disease resistance, supplemented by breeding experiments. Professor Stuart has kindly supplied the following summary of his results to date:[a]

Eight varieties were under trial in 1903—Dakota Red, Enormous, Green Mountain, Rustproof, Squire, Sir Walter Raleigh, and two of Manum's unnamed seedlings. In 1904 the same varieties were used, with the addition of June, Mammoth Gem, Minister, New Queen, State of Maine, Sutton's Discovery, nine more of Manum's seedlings, *S. commersonii* from Doctor Heckel, of France, a Peruvian variety from the United States Department of Agriculture at Washington, and four Mexican varieties furnished by Mr. C. G. Pringle. The latter included two cultivated varieties termed Monterey and Mexican, and the two wild species, *S. polyadenium* and *S. stoloniferum*. Observations have been made as to both foliage and tuber resistance. As to foliage, none was wholly free from blight, but there was a marked difference, some being quickly and entirely destroyed, while others suffered only slightly. In 1903 Rustproof headed the list in this respect, and Dakota Red was second. In 1904 those showing greatest foliage resistance were as follows, in the order of their resistance: Monterey, *S. commersonii*, *S. polyadenium*, Rustproof, Sutton's Discovery, June, Mexican, Mammoth Gem, and Manum's No. 3. Dakota Red did not equal its 1903 record.

Judged by resistance of tubers to rot, Dakota Red made the best showing of the varieties which were tested for two seasons, but there was some rot in it both years. Of those added to the series of 1904 several varieties gave a crop of tubers entirely free from rot, namely *S. polyadenium*, *S. commersonii*, Sutton's Discovery, June, and the two Mexican varieties. It is noteworthy that these are likewise the varieties which showed the least blighting of the foliage. Possibly the absence of rot is in some degree attributable to the lessened amount of infection of tubers from vines in consequence of this, although there were adjacent plants showing badly diseased foliage.

Selection.—In 1903 a few plants in the varieties grown were observed to remain green longer than the others. The tubers from these were saved and were planted in 1904 along with others of the same variety that succumbed much earlier. So far as could be noted no increased disease-resistant qualities were transmitted to the offspring of these plants.

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[a] For further details see Stuart, W., Disease-Resistant Potatoes, Vermont Exp. Sta. Bul. 115 (May, 1905).

In view of the limited number of varieties tested and the consequent restricted scope of observation, it would hardly be justifiable as yet to give an expression of opinion as to the probable outcome of such a line of investigation. These observations are to be continued on a much larger scale the coming season.

Hybrid and other seedlings.—Seedlings were grown in 1903 from the Mexican species supplied by Mr. Pringle—*S. polyadenium*, *S. stoloniferum*, and *S. bulbocastanum.* This number has recently been augmented by *S. verrucosum* and a wild form of *S. tuberosum.* In 1904 some of these were successfully hybridized with the cultivated potato.

While it is yet too early to say very much regarding the possibilities of developing a commercially desirable disease-resistant variety of potato through the hybridization of wild species with our cultivated varieties, there seems good reason for believing that improvement may result from such crossing, especially as to disease resistance.

In addition, a large number of seedlings of the common potato were grown in 1904. Among this number several vigorous-growing plants were noted, which remained quite green up to the time of digging. Some 50 of the more promising of these were saved for trial the coming season. Selections were based on vigor of vine, size and yield of tubers, and freedom from rot.

One of the most interesting and instructive features of the seedling experiment was the object lesson it presented of the extreme vigor of some of the plants, showing quite plainly that one of the best sources for increasing the vigor lies in the production of new varieties from seed. Proper fertilization and good tillage are also important aids in increasing the vigor and disease-resisting powers of the vine.

While the data in hand do not warrant broad generalizations, the following inferences are drawn by Professor Stuart:

(1) Some varieties are less subject to vine injury than others.

(2) Some show a greater tuber resistance to rot than others.

(3) With some there seems to be a fairly close relation between resistance of vine to disease and of the tuber to rot.

(4) Selection has not given visible increase of resistance.

(5) Hybridization and the growing of seedling plants, followed by careful selection, seem to offer a more logical method of securing disease-resistant varieties than does selection.

INFORMATION SECURED BY A CIRCULAR OF INQUIRY.

In order to secure all information possible as to the relative merits of the varieties now before the public, a circular letter of inquiry was sent recently to various experiment station officers and to about two hundred potato specialists in the United States and Canada[a] asking their opinions and the basis for them. There was a surprising lack of agreement upon any one variety as being especially disease resistant. The replies indicate several things: (1) That very few American potato specialists have up to the present time given careful attention to this question; (2) that there are few varieties in common use which have preeminent worth as disease resisters; and (3) that in so large a geographical area local conditions affecting culture and disease are so widely variant as to prevent close comparisons or broad generalizations. No less than 38 varieties were commended as showing resistance to blight or rot. Of these, 26 were commended only once, while the other 12 were favorably spoken of by two or more persons. Still other varieties were mentioned, but not with sufficient positiveness to entitle them to a place in the following list. Those named more than once, with the locality in which they were indorsed, are as follows:

TABLE III.—*The best varieties of potatoes in the United States and Canada, as reported by various experiment station officers and potato specialists.*

Variety.	Number of indorsements.	Localities in which commended.
Dakota Red	10	Canada (4); Maine (3); Massachusetts; Michigan; New York.
Irish Cobbler	5	New York (2); Maine; Ohio; Rhode Island.
Green Mountain	5	Maine (2); Massachusetts (2); Vermont.
Doe's Pride	3	Maine (2); Michigan.
Norcross	3	Maine; New York; Vermont.
White Beauty	2	Maine; Minnesota.
Professor Maercker	2	Canada; Rhode Island.
Ionia Seedling	2	New York.
Quick Lunch	2	Pennsylvania; Vermont.
Rustproof	2	Vermont.
Sir Walter Raleigh	2	Minnesota; New York.
Vermont Gold Coin	2	Pennsylvania; New York.

The following varieties were mentioned once each, the commendation coming from the locality mentioned in parentheses: American Wonder (Minnesota); Babbitt (Maine); Bonanza (New York); Boss (Vermont); Buffalo (Maine); Burbank (New York); Cambridge Russet (New York); Carmen No. 3 (Ohio); Clarke's Pride (Maine); Clay Rose (Minnesota); Crines Lightning (New Jersey); Delaware (Minnesota); Enormous (New York); Gem of Aroostook (Rhode Island); Gloria (Rhode Island); Harris Snowball (New York); Holborn Abundance (Canada); Imperial Mills Prize (Maine); Keeper (New Hampshire);

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[a] The writer is indebted to the following experiment station officers for helpful advice: Professors Macoun, Canada; Woods, Maine; Rane, New Hampshire; Stuart, Vermont; Brooks, Massachusetts; Wheeler and Adams, Rhode Island; Fraser and Stewart, New York; Buckhout, Pennsylvania; Halsted, New Jersey; Selby, Ohio; Taft, Michigan; and Green, Minnesota. Much information has been secured from the replies of leading potato growers and seed dealers. It is regretted that it is impracticable to give detailed credit to these correspondents.

Professor Kuehn (Rhode Island); Million Dollar (Michigan); Orange Blossom (Vermont); Rural New Yorker No. 2 (Vermont); Scabproof (Wisconsin); Squier (Vermont); Star of the East (Maine); State of Maine (Canada); Swiss Snowflake (Canada); Virgirosa (Vermont); Westfield (Vermont); White Scotch King (Minnesota). In addition three unnamed varieties received favorable mention from Vermont.

From these reports it is observed that certain varieties like Dakota Red, Rustproof, and Keeper have very well proved powers of disease resistance, but lack other desirable characters to make them popular varieties. Several of the standard main-crop varieties are in some degree disease resistant, and doubtless owe their general popularity, in a measure, to this fact, although it has not been clearly defined. To this group belong Carmen's best productions—Carmen No. 3, Sir Walter Raleigh, Rural New Yorker No. 2, and Rural Blush—Green Mountain, State of Maine, Delaware, Enormous, and White Beauty. Irish Cobbler is highly spoken of as disease resistant, but it is a question whether this may not be in part due to its early maturity, by virtue of which it escapes the worst ravages of Phytophthora.

There is also a very promising series of new seedlings which should be carefully watched as to disease-resisting characters, among which may be especially mentioned Norcross, Star of the East, and Babbitt (Johnson Seed Company); Vermont Gold Coin (Burpee); Ionia Seedling (Dibble); Harris Snowball (Harris & Co.).

It is encouraging to learn from the replies that several of the newer German and English varieties which are reputed disease resisting in their home countries have upon trial in America made a good showing. This is evidenced by the reports from the Rhode Island and Canada stations favorable to Professor Maercker, Gloria, Professor Kuehn (German), Holborn Abundance (English), and Swiss Snowflake.

RESISTANCE TO SCAB.

It is a matter of common observation that some varieties of potatoes are more liable to scab than are others. Reference has been made earlier in this publication to conclusions to this effect reached in Germany. So far as known the only American publication recording the results of comparative trials as to scab resistance is that made by the Vermont Agricultural Experiment Station in 1901–2.[a] Thirteen varieties were tested in 1901 and fourteen in 1902 in soil badly infested with scab germs. While all showed some scab, there was a considerable difference in the amount. Sir Walter Raleigh made a good showing both years, but an unnamed seedling sent by Mr. A. E. Manum, his No. 56, was more highly resistant. These trials established the writer's confidence that still more resistant strains may be secured by breeding and selection. Prof. William Stuart, of the Vermont station, has undertaken this work in connection with the development of resistance to blight and rot.[a] He has made further trials during the last two years, but without conclusive results as yet.

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[a] Jones, L. R., and W. J. Morse. Vermont Exp. Sta. Report, XV: 225 (1902).

A request for information as to relative scab resistance was inserted in the circular of inquiry, already referred to, recently sent to American potato specialists. Most of the replies to this question were negative in character, but a number gave interesting information, some of which is especially pertinent. The strongest evidence as to scab resistance comes from Mr. Hiram Presley, of Port Huron, Mich., a potato specialist, who has tested hundreds of varieties during the past thirty years. He commends the Cambridge Russet as practically exempt from scab. Mr. Frank Paddock, of Perry, N. Y., gives like evidence.

Carmen No. 3 is highly spoken of as scab resisting by several growers in Ohio, New York, and Vermont, but one Michigan correspondent condemns it.

American Giant receives strong indorsement from Freehold, N. J., and vicinity; Salzer's Scabproof from Wisconsin, and Aurora from Vermont. Favorable reports come from New York regarding Sir Walter Raleigh and Irish Cobbler, and from Canada regarding McIntyre.

The following were each commended by one correspondent from the localities mentioned in parentheses: Best (Maine); Doe's Pride (Maine); Early Freeman (Ontario); Keeper (New Hampshire); Seneca Beauty (Michigan); Squier (Vermont); White Beauty (Michigan); White Elephant (New Jersey); White Scotch King (Minnesota).

On the other hand, the Early Ohio and some of its seedlings are condemned as especially liable to scab. Early Rose, Bliss Triumph, and Beauty of Hebron are also reported to scab badly.

It is encouraging to note that in some cases the same variety is rated as in a high degree resistant to both diseases, the scab and the late-blight and rot. A similar coincidence will be found if a comparison is made of the lists of German varieties showing resistance to the several diseases discussed earlier in these pages, and the same thing was observed in some degree with the English varieties.

This indicates that the attributes which give power of resistance against one disease are not incompatible with those operative against another. Indeed, it is not unlikely that the general characteristics of disease resistance may prove to be similar or the same for these various maladies. If so, it will prove the easier to secure the model potato, which, while possessing that which is desirable in quality and productiveness, shall, in addition, show the highest degree of resistance to the various diseases. This is an ideal worth striving for.

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[a] Vermont Exp. Sta. Bul. 115, p. 139.

SUMMARY.

The aim of this bulletin is to present in concise form what is known about disease resistance of potatoes. Much of this information is from European sources.

Certain minor diseases of obscure nature, but apparently nonparasitic, are first considered—the internal brown spot, filosité, and leaf-spot. Among remedial measures for each is the selection of resistant varieties.

Scab diseases of tubers are in most, and perhaps in all, cases of parasitic origin—fungous or bacterial. Apparently the variety of these is greater in Europe than in America, but the severity is less in Europe. It is undecided to what extent the American type of scab occurs in Europe, so a close comparison of conditions and remedies is not practicable. In Germany certain varieties are known to be more scab resistant than others, among them being Richter's Imperator, Professor Wohltmann, and Irene. The same is true in America, Cambridge Russet leading the list, so far as is known. Other American varieties showing a considerable degree of resistance are Carmen No. 3, American Giant, Sir Walter Raleigh, and Irish Cobbler. Scabproof and Aurora are also highly commended for scab resistance.

Various stem diseases of the potato are known. The commonest type in Europe is termed blackleg (Schwarzbeinigkeit), a bacterial disease. It is not known to occur in America, but it resembles certain maladies which do occur here and which are as yet imperfectly understood. Varietal resistance to blackleg is not fully established, but apparently Dabersche and certain similar thick-skinned, starch-rich late varieties are more resistant than thin-skinned, starch-poor early varieties of the Rose type. Factor and Up-to-Date showed a considerable degree of resistance to blackleg in England. La Czarine and other varieties are reported to show resistance to a bacterial stem disease in France.

The late-blight and rot due to the fungus *Phytophthora infestans* occurs more commonly in Europe than in America. Attention has been given for many years to relative varietal susceptibility to this disease, especially in Great Britain and in Germany. Varieties of superior disease resistance are known in both countries, and a number of the most promising from these and other European sources have been imported for trial.

The following statements are tentatively formulated as to the nature of resistance toward blight and rot and the character of the varieties exhibiting it:

(1) Disease resistance in potatoes is relative, not absolute, no variety known being wholly proof against late-blight and rot.

(2) It seems related to general vegetative vigor, and is therefore in a measure dependent upon cultural and developmental conditions and tends to decrease with the age of the variety.

(3) It can be restored by originating new varieties from seed, especially of hybrid origin. Not all seedlings show superior disease resistance.

(4) The use of other species of tuber-bearing Solanums for hybridizing offers some promise, but no practical results have yet been secured.

(5) Possibly the disease resistance in established varieties can be improved by selection, but this has not been proved.

(6) Early varieties may escape the disease by maturing before it becomes epidemic, but when similarly exposed they are as a class less resistant than late varieties.

(7) The source of seed tubers is a matter of importance, northern-grown seed giving plants of superior disease resistance in Europe. Seed from a crop that was not too highly fertilized is probably preferable. Possibly tubers are better for seed purposes if dug before they reach full maturity.

(8) High fertilization, especially with nitrogenous manures, lowers the power of the plant to resist both blight and rot.

(9) Varieties relatively rich in starch are more resistant to rot; those richer in protein are more susceptible to it.

(10) So far as skin characters are an index, the red varieties with thick and rough skin seem more resistant as a class than the thin-skinned white varieties.

(11) So far as stem and foliage characters are concerned, the evidence favors the stem that is hard, rough, and rather woody at the base, and the leaf that is small, somewhat rough, and dark colored.

The varieties rated highest as to disease resistance in England are Evergood, Discovery, Royal Kidney, Northern Star, Sir John Llewelyn, King Edward VII, Eldorado, and Factor.

In Germany and Holland the following represent the best types: Mohort, Irene, Geheimrat Thiel, Professor Wohltmann, Boncza, Eigenheimer, and Paul Krüger.

In Belgium and France no improvement as to disease resistance has been made over the best English and German types.

In America, trials as to disease resistance have been conducted at some of the experiment stations, notably in Vermont, where experiments in breeding and selection for increased resistance are under way. These results have been correlated with information recently secured by a circular of inquiry addressed to a large number of potato specialists in the Northeastern States and in Canada. From these it appears that a wide variation is shown in disease resistance among the varieties now in cultivation in America, but that no one variety is preeminent.

Among those which have been widely tested, the following deserve mention as of the resistant class: Dakota Red, Rustproof, Irish Cobbler, Sir Walter Raleigh, Doe's Pride, and White Beauty. Certain European varieties of the disease-resistant type seem to retain that character when grown in this country, e. g., Professor Maercker and Sutton's Discovery. There is much of promise in certain new varieties under trial at the Vermont station. Several new sorts of reputed disease resistance have recently been placed on the market by American seedsmen, e. g., Harris's Snowball, Dibble's Ionia Seedling, Burpee's Vermont Gold Coin, and Johnson's Norcross, Star of the East, and Babbitt. Those having opportunity should carefully observe the relative disease resistance of these and also of other new varieties.

The evidence at hand seems to justify the hope that the coordinated efforts of potato specialists working from both the practical and the scientific standpoints may soon result in the development of varieties of potatoes combining general excellence with a high degree of disease resistance. All who can do so are urged to aid toward the accomplishment of this end.

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